RAPID MULTI-COMET SAMPLE RETURN USING SWARMS OF TINY INTERPLANETARY SPACECRAFT

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Introduction: Basic characterization of the chemistry and mineralogy of the presolar cloud is a major unsolved problem in Planetary Science. Laboratory analyses of cometary materials collected in the stratosphere[1], in Antarctic ices[2], and returned by the Stardust spacecraft [3] have shown that comets are heterogeneous on a submicron scale, and contain a major, coarse-grained refractory component that is inconsistent with interstellar dust[4]. Nevertheless, comets are likely to be a reservoir of minimally unaltered, fine-grained pre-solar dust and organics that do not readily survive atmospheric entry, terrestrial weathering, or hypervelocity capture in aerogel or Al foils. Return of cometary materials that avoid these pathological sampling effects is therefore a high priority. One approach is to collect a large (≥50g) sample from the surface a single comet with a New Frontiers class (~$1B) mission architecture[5]. However, a multi-gram sample is orders of magnitude in excess of that required to address open questions (e.g., the nature of organics, the presence of GEMS) and to provide basic characterization of fine-grained material. Surface samples are also unlikely to be more pristine than coma samples. **Rather than collection of a large surface sample from a single comet with an expensive, technically risky mission, we suggest that the emphasis instead should be on the collection of many small (~µg) coma samples, closely matching the natural size scale of cometary materials that we observe in the laboratory, from dozens of comets. Such samples would still contain the equivalent in mass of hundreds of 10µm particles. Such an approach would dramatically increase scientific yield and reduce cost and risk, while accelerating mission rapidity and cadence.**

Berkeley Low-Cost InterPlanetary Spacecraft (BLIPS): Spectacular advances in the last decade in microelectronics and MEMS (Micro-electromechanical systems) technology enable the development of tiny (~10g), inexpensive, autonomous spacecraft for inner solar-system exploration and sample return. Almost all components of such spacecraft are available commercially and off-the-shelf (COTS). COTS low-power linux Gumstix computers provide computation. COTS 100 cm^2 solar arrays and lithium batteries provide power. Imaging of bright (m<5) stars, the five inner planets, and targeted cometary nuclei using COTS cell-phone cameras provide cruise and terminal navigation. COTS 5W lasers with 1 cm aperture and a COTS single photon avalanche detector (SPAD) with a 3 cm diameter plastic Fresnel lens provide near-earth communication. Highly oriented pyrolytic graphene (HOPG) radiator fins provide thermal control. ~1 m^2 solar sails provide propulsion, steering, and attitude control, using MEMS inchworm motors that control carbon-fiber solar sail shroud length. This technology is the only component that is not commercially available. We are currently doing thermal-vac testing of inchworm motors at SSL, and plan for LEO test flights of BLIPS in the near future.

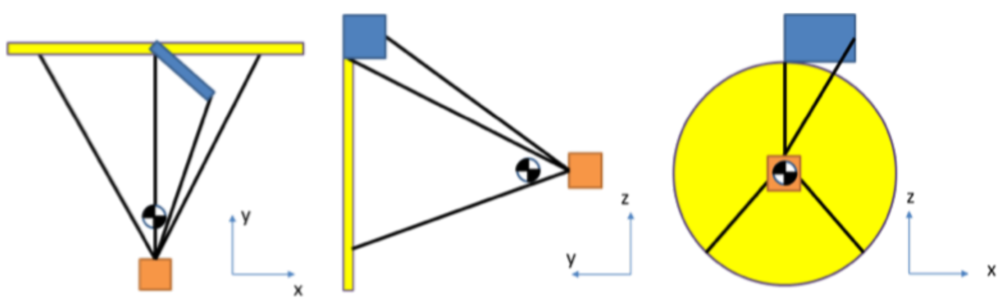

Figure 1. Diagram of spacecraft design showing solar sail (yellow circle), roll flag (blue square), mini-bus (orange square), carbon fiber tethers (black lines), and center of mass (black and white circle).

Mission architecture for cometary sample return: Swarms of BLIPS released from a conventional spacecraft at approximately GEO will target dozens of comets. Once released, the BLIPS will operate autonomously. A sample return mission to e.g., comet C-G/67P requires a round-trip flight time of ~5 years. BLIPS will rendezvous with comets for low-speed coma sample collection. For typical cometary dust production rates, a few days of exposure at 25 km stand-off yields ~1µg coma samples that would be stored in a 1 cm^2 container with a MEMS-operated lid. Multiple BLIPS per target comet reduce overall risk through redundancy. BLIPS would be recovered at GEO using a conventional spacecraft, with a Stardust-like re-entry and recovery at Dugway Proving Grounds, and curation at NASA/JSC.

References:[1] Bradley, J.P. 2003, Treatise on Geochemistry 1, 711. [2] Brownlee, D., et al 2006, Science 314, 1711. [3] Duprat, J. et al. 2010, Science 328, 742 [4] Westphal, A.J., et al. 2019, ApJ 872, 66 [5] Vision and Voyages for Planetary Science in the Decade 2013-2022, National Academies Press, 2010.